RESEARCH ARTICLE

# Comparing 3D MERGE MRI and 2D MRI for Rotator Cuff Tear Evaluation and Surgical Planning; A Cross-Sectional Prospective Study

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## Abstract

**Objectives:** Accurate diagnosis and characterization of rotator cuff tendon (RCT) tears are crucial for optimal treatment planning. This study compared the diagnostic performance of 3D Multiple Echo Recombined Gradient Echo (MERGE) MRI with conventional 2D MRI for the assessment of RCT tears and surgical planning.

**Methods:** Sixty-two patients with suspected RCT tear underwent shoulder MRI using standard 2D and 3D MERGE protocols, followed by arthroscopic evaluation. RCT tears were classified as crescent, longitudinal, or massive. The sensitivity, specificity, and accuracy of 3D MERGE and 2D MRI were calculated using arthroscopy as the reference standard. Inter-observer agreement was assessed using kappa statistics.

**Results:** Arthroscopy confirmed crescent tears in 25 patients (40%), longitudinal tears in 9 patients (15%), and massive tears in 28 patients (45%). 3D MERGE MRI demonstrated higher accuracy for tear shape classification compared to 2D MRI (90.5% vs. 79.6%, $P < 0.05$). Sensitivity and specificity were markedly improved with 3D MERGE MRI, particularly for crescent tears (sensitivity 88.2% vs. 70.6%, specificity of 94.6% vs. 86.5%, $P < 0.05$). The inter-observer agreement was excellent for 3D MERGE MRI (kappa = 0.91) and good for 2D MRI (kappa = 0.76).

**Conclusion:** 3D MERGE MRI exhibited superior diagnostic performance and reliability compared to 2D MRI in characterizing RCT tears. The enhanced accuracy of 3D MERGE MRI may facilitate preoperative assessment and surgical decision-making for RCT tears.

**Level of evidence:** II

**Keywords:** Rotator cuff tendon tear shape, Sensitivity and specificity, Shoulder MRI, Three-dimensional magnetic resonance imaging

## Introduction

Rotator cuff tendon (RCT) tears are prevalent shoulder injuries that can lead to pain, weakness, and functional impairment, often requiring surgical intervention.[1,2] Accurate diagnosis and characterization of the shapes of the RCT tear are crucial for determining the most effective treatment approaches and predicting patient outcomes.[3-5] However, conventional 2D MRI may lack the accuracy and reliability needed to identify and categorize the morphology of RCT tears. This imaging technique often struggles to visualize complex tear morphologies due to its dependence on predefined imaging planes. Crescent-shaped tears, for instance, located in the anterior or posterior supraspinatus tendon are particularly challenging to characterize in sagittal or coronal planes. Studies have noted that 2D imaging may fail to accurately delineate the true dimensions of these tears, leading to misclassification and suboptimal surgical planning.[6-9]

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3D MRI methods, which employ isotropic imaging and multiplanar reconstruction, have been developed to overcome these limitations.[10,11] These techniques facilitate the imaging of the rotator cuff tendon in any desired plane without compromising resolution or signal-to-noise ratio.[11,12] Previous studies have demonstrated the superior accuracy of 3D MRI compared to 2D MRI in classifying rotator cuff tears, particularly in detecting complex tear configurations.[10,13] The isotropic properties of 3D MRI allow visualization in any plane without sacrificing image quality and spatial resolution.[11]

Precise classification of rotator cuff tear shape has significant implications for surgical planning and prognostication following repair.[3,4] Crescent-shaped tears exhibit superior outcomes with arthroscopic repair, while massive tears present greater challenges and are associated with higher failure rates.[14,15] However, the complex anatomy of crescent-shaped tears within the anterior or posterior supraspinatus tendon complicates their visualization and characterization on standard 2D MRI planes. 3D MRI techniques may offer a more comprehensive delineation of the true shape and dimensions of various patterns of rotator cuff tears.[16]

The objective of this study was to compare the diagnostic accuracy of 3D MERGE MRI with conventional 2D MRI in classifying rotator cuff tears prior to surgery. We hypothesized that 3D MERGE MRI would yield improved sensitivity, specificity, and accuracy in categorizing the shape of rotator cuff tear compared to 2D MRI.

## Materials and Methods

### *Study Design and Patient Selection*

This cross-sectional prospective study, conducted from August 2020 to March 2023, included 62 patients with full-thickness RCT tears at Shariati Hospital in Tehran, Iran. Diagnosis was confirmed through physical examination, 2D MRI, and arthroscopic evaluation. Exclusion criteria included previous shoulder surgery, age over 70, muscular atrophy, fractures, other shoulder conditions, improper imaging, poor image quality, and partial tears. While these exclusion criteria ensured a homogeneous study population, potential biases related to age, muscular atrophy, and previous surgeries were unavoidable.

### *Imaging Parameters and Evaluation*

Conventional 2D MRI examinations were performed using a 3.0 Tesla (T) Discovery™ MR750w scanner (GE Healthcare, Chicago, IL, USA). The 3T MRI system was chosen for its superior spatial resolution and signal-to-noise ratio, which are critical for visualizing small and complex rotator cuff tears. The protocol included proton density fat-saturated (PDFS) sequences in the sagittal (slice thickness: 3 mm; repetition time [TR]: 3000 ms; echo time [TE]: 44 ms; field of view [FOV]: 160 mm; matrix: 288×288), coronal (slice thickness: 3 mm; TR: 3000 ms; TE: 44 ms; matrix: 288×288), and axial (slice thickness: 3 mm; TR: 3000 ms; TE: 44 ms; matrix: 292×292) planes, with an average scan time of 20 minutes. The PDFS sequences provide high contrast between fluid and soft tissues, making them particularly useful for evaluating rotator cuff tears. Additional sagittal T1-weighted (slice thickness: 3 mm; TR: 510 ms; TE: 8.1 ms; FOV: 160 mm; matrix: 384×192) and coronal T2-weighted (slice thickness: 3 mm; TR: 5000 ms; TE: 99 ms; FOV: 160 mm; matrix: 320×320) sequences were also acquired to assess bone marrow and muscle/tendon abnormalities, respectively.

For the 3D MRI, an additional Multiple Echo Recombined Gradient Echo (MERGE) sequence was obtained in the coronal plane using the following parameters: FOV: 22.4 cm; matrix size: 224×224; slice thickness: 1 mm; TR: minimum; TE: minimum full (13.1 ms); flip angle: 5°; number of excitations (NEX): 1; bandwidth: 41.67 kHz; average scan time: 4 minutes and 55 seconds. The MERGE sequence is a T2*-weighted sequence that generates isotropic voxels, allowing for high-resolution, multi-planar reconstructions without comprising image quality.

The 3D MERGE MRI sequence was chosen for its superior isotropic resolution and T2*-weighted contrast, which enhance the visualization of rotator cuff tendons and tear morphologies. Alternative 3D techniques, such as 3D PDFS, were excluded from this study due to their lower spatial resolution and limited capability for high-quality multiplanar reconstructions compared to MERGE sequences, as supported by prior research.[12,17,18] Images were analyzed and post-processed for 3D reconstruction using the Advantage Workstation (GE Healthcare, version 4.7) and the Volume Viewer application. Manual segmentation of the injured rotator cuff muscles and tendons was performed on the coronal MERGE sequence using Vitrea software (version 4.1, Vital Images, Minnetonka, MN, USA) by a single trained technologist.[19] The segmented structures were then rendered using the volume rendering technique to create 3D visualizations of the rotator cuff tears [Figures 1 and 2]. For the evaluation of rotator cuff tear shape on 2D MRI, PDFS sequences in the sagittal and coronal planes were used. The average acquisition time for these two sequences combined was 9 minutes. Figures 1 and 2 illustrate representative samples of 3D MERGE MRI reconstructions and corresponding 2D PDFS images for crescent-shaped and longitudinal rotator cuff tears, respectively.

### *Classification of RCT Tear Shapes*

The shape of the RCT was categorized according to the criteria established by Burkhart *et al.*, which include massive, crescentic, or longitudinal (U and L shapes). A tear is defined as crescent-shaped if its width (anteroposterior dimension) is greater than its length (mediolateral dimension), with the length being less than or equal to the width and less than 2 cm. A longitudinal tear is characterized by its length being greater than its width (L > W and W < 2 cm). Tears were classified as massive if their sagittal and coronal dimensions exceeded 2 cm (L ≥ 2 cm and W ≥ 2 cm). Both 2D and 3D images were analyzed using the same RCT tear categorization.[11-13] For the calculation of diagnostic accuracy metrics, results from 2D or 3D MRI that were inconclusive were treated as negative.

### *Imaging Interpretations*

Two musculoskeletal radiologists, who were blinded to the arthroscopic results, independently reviewed both 2D and 3D images in separate sessions. They utilized a standardized MRI reporting checklist[20] and adhered to rotator cuff injury guidelines.[13,21]

rotator cuff injury guidelines.[13]

### *Evaluation of the Accuracy of Pre-operative and Surgical Planning*

An orthopedic surgeon used both 2D and 3D MRI reports to finalize a pre-operative checklist. Post-operative assessments were completed by a blinded researcher. The median time interval between the MRI and arthroscopy was approximately two weeks.

### *Statistical Analysis*

Continuous variables were compared using an independent samples t-test, while categorical variables were analyzed using Chi-square or McNemar tests. The sensitivity, specificity, and accuracy of MRIs were calculated based on data from the Gold Standard Technique. Inter-observer agreement was assessed using kappa statistics, and data were analyzed with SPSS version 22, with significance defined as P-values below 0.05.

## Results

### *Study Population Characteristics*

We enrolled sixty-two patients who underwent both 2D and 3D MERGE MRI prior to arthroscopic examination of their shoulders. The mean age of the participants was 57.43 ± 6.32 years (mean ± SD) and 74% of the patients were male. The inter-reader reliability for image interpretation was excellent for 3D MRI (kappa = 0.91; 95% confidence interval [CI] 0.83-0.99) and good for 2D MRI (kappa = 0.76; 95% CI 0.64-0.88).

### *Imaging vs. Arthroscopy Results*

Based on 3D MRI interpretation, the orthopedic surgeon accurately characterized the number of tendons involved in 87% of cases and correctly assessed tear location and repairability in 83% and 81% of rotator cuff tears, respectively, when compared to arthroscopic documentation. In contrast, when relying solely on standard 2D MRI interpretation, the orthopedic surgeon accurately characterized the number of tendons involved in 72% of cases. The surgeon correctly assessed tear location and repairability in 76% and 74% of rotator cuff tears, respectively, compared to the arthroscopic findings.

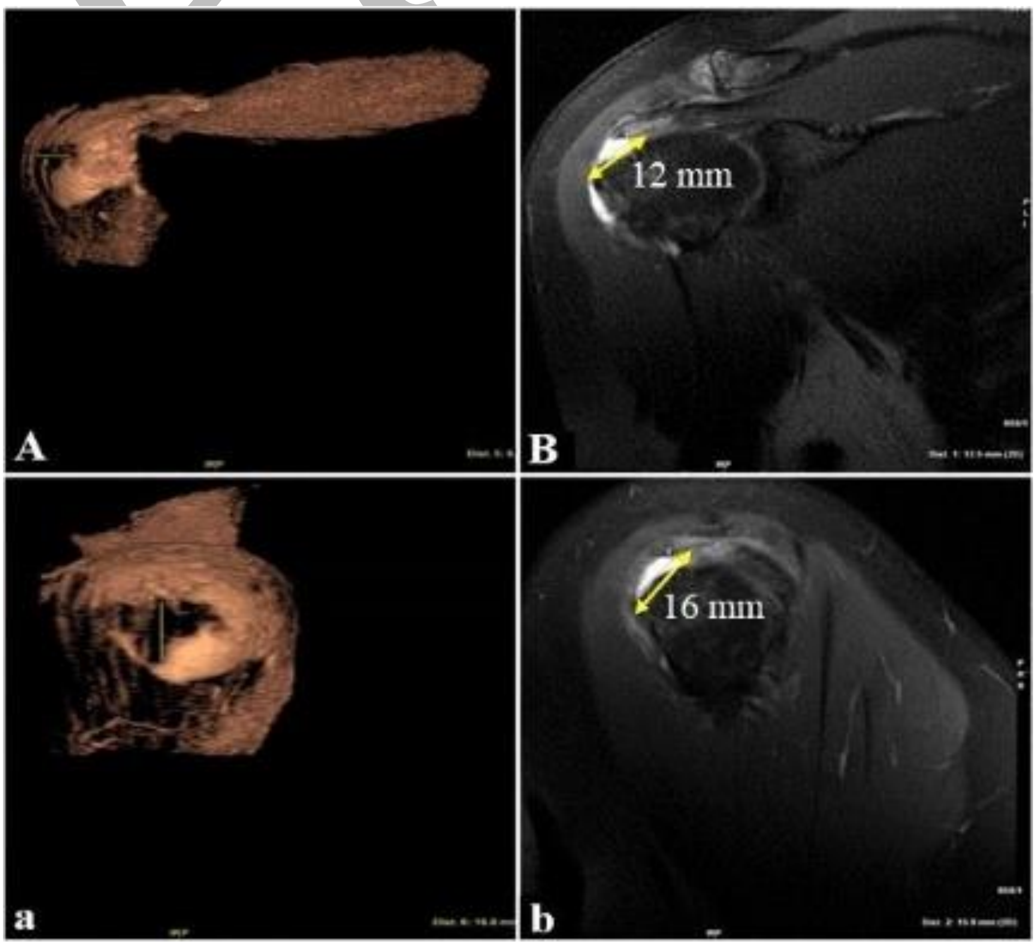


**Figure 1. Crescent shape tears in 3D MERGE MRI manually reconstructed images; coronal (A) and sagittal (a) manual reconstructions demonstrate more apprehensible characterization of crescent shape tears. Crescent shape tears in 2D routine standard protocol images; coronal (B) and sagittal (b) show 12 mm and 16 mm mediolateral and anteroposterior gaps, respectively, in the supraspinatus tendon insertion, suggestive of crescent shape tear**

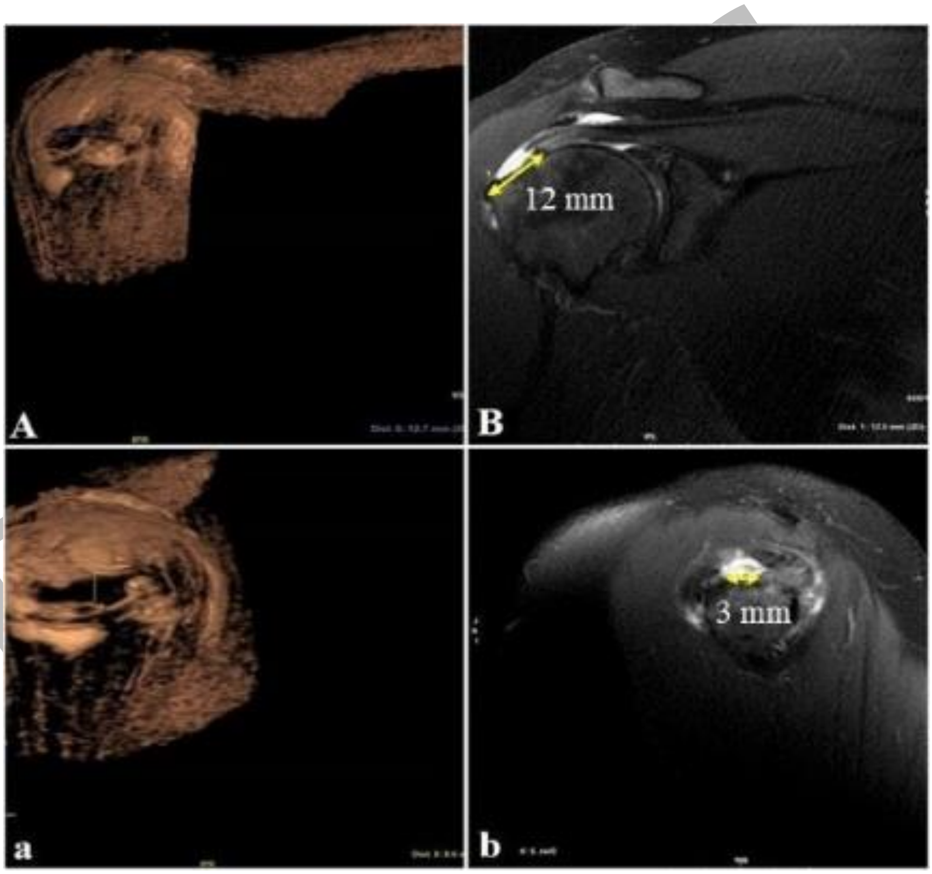


**Figure 2. Longitudinal shape tear in 3D MERGE MRI manually reconstructed images; coronal (A) and sagittal (a) reconstructed images revealed better definition and visualization of longitudinal complete supraspinatus tendon tear. Longitudinal shape tear in 2D routine protocol images; coronal (B) and sagittal (b) show complete supraspinatus tendon tear with 12 mm and 3 mm mediolateral and anteroposterior dimensions, respectively**

Arthroscopic examination confirmed that 28 patients (45%) had massive tears, 25 patients (40%) had crescent tears, and 9 patients (15%) had longitudinal (U- or L-shaped) tears. Figure 3 demonstrates the frequency of RCT tear categories by gender [Figure 3]. Male patients (23, or 54%) were more likely to have massive tears compared to female patients (3, or 19%). Conversely, female patients (9, or 56%) were more likely to have crescent tears than male patients (15 or 35%).

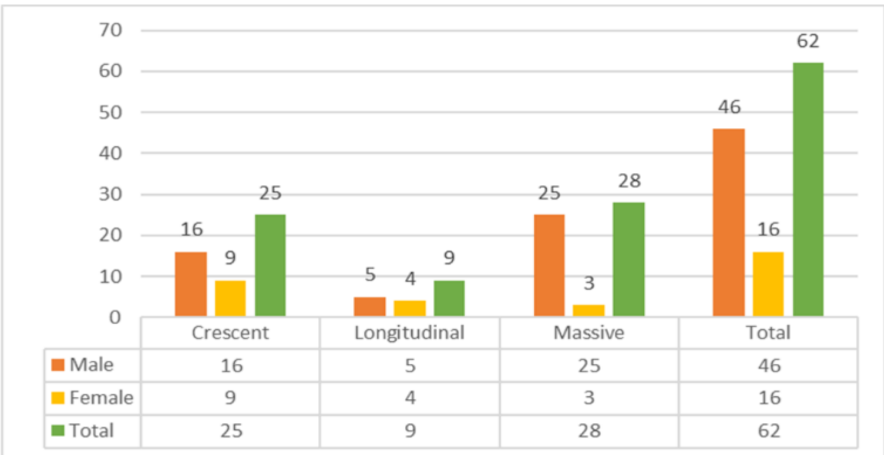


**Figure 3. Frequency of rotator cuff tear shapes by gender**

2D MRI detected crescent tears in 24 patients (39%), massive tears in 23 patients (37%), and longitudinal tears in 15 patients (24%). In contrast, 3D MRI identified massive tears in 27 patients (44%), crescent tears in 25 patients (40%), and longitudinal tears in 10 patients (16%). The comparison of 2D and 3D MRI for diagnosing RCT tear types is shown in [Table 1].

***Sensitivity, Specificity, and Accuracy of Diagnostic Modalities***

As presented in Table 2, 3D MERGE MRI demonstrated higher sensitivity, specificity, and accuracy compared to 2D MRI across all tear shapes. For crescent tears, 3D MRI demonstrated a sensitivity of 88.2% (95% CI 63.6-98.5), a specificity of 92% (95% CI 76.6-98.2), and an accuracy of 90.1% (95% CI 82.5-95.1) [Table 2]. In contrast, the corresponding measures for 2D MRI were lower, with sensitivity at 70.6% (95% CI 44.0-89.7), specificity at 80% (95% CI 60.9-91.1), and accuracy at 75.3% (95% CI 65.1-83.7). This trend was consistent across other tear shapes as well. The overall diagnostic accuracy for all shapes was 90.5% (95% CI 86.0-94.0) for 3D MRI, compared to 79.6% (95% CI 74.1-84.2) for 2D MRI.

***Adverse Events***

In the research conducted, no incidents of negative effects resulting from the MRI examinations or arthroscopic interventions were reported.



**Table 1. Frequency and percentage of rotator cuff tendon tear shapes based on 2D MRI, 3D MERGE MRI and arthroscopic confirmation**

| | | Tear Shape | | |
|---|---|---|---|---|
| | | **Crescent** | **Longitudinal** | **Crescent** |
| **Modality N (%)** | *2D MRI* | 24 (39%) | 15 (24%) | 23 (37%) |
| | *3D MRI* | 25 (40%) | 10 (16%) | 27 (44%) |
| | *Arthroscopy* | 25 (40%) | 9 (15%) | 28 (45%) |

N: Number

**Table 2. Comparison of sensitivity, specificity, and accuracy of 2D MRI and 3D MERGE MRI in diagnosing rotator cuff tendon tear shapes**

| Imaging Modality | Tear Shape | Sensitivity % (95% CI) | Specificity % (95% CI) | Accuracy % (95% CI) |
|---|---|---|---|---|
| **2D MRI** | Crescent | 70.6 (44.0-89.7) | 80 (60.9-91.1) | 75.3 (65.1-83.7) |
| | Longitudinal | 83.3 (35.9-99.6) | 88.9 (75.7-96.6) | 86.1 (77.3-92.5) |
| | Massive | 78.9 (52.3-93.6) | 95.8 (83.3-99.5) | 87.4 (79.1-93.2) |
| | **Total** | **77.6 (67.8-85.6)** | **88.2 (79.4-94.1)** | **79.6 (74.1-84.2)** |
| **3D MRI** | Crescent | 88.2 (63.6-98.5) | 92 (76.6-98.2) | 90.1 (82.5-95.1) |
| | Longitudinal | 83.3 (35.9-99.6) | 94.4 (81.9-99.3) | 88.9 (81.0-94.3) |
| | Massive | 89.5 (65.5-98.2) | 95.6 (82.8-99.2) | 92.6 (86.3-96.5) |
| | **Total** | **87.0 (77.9-93.4)** | **94.0 (86.2-98.0)** | **90.5 (86.0-94.0)** |

CI: Confidence Interval

## Discussion

This study compares the diagnostic accuracy of 3D multiplanar MRI MERGE sequence reconstruction with that of 2D MRI in detecting and categorizing rotator cuff tendon injuries for preoperative planning. Our findings indicate that 3D MERGE MRI sequence reconstruction demonstrates greater accuracy, sensitivity, and specificity across all types of tears compared to 2D MRI. The most significant difference was observed in the sensitivity rates for crescent tears, which were 88.2% for 3D MRI and 70.6% for 2D MRI. Our results suggest that 3D MRI with multiplanar reconstruction is a more effective imaging technique than 2D MRI for evaluating the shape and size of rotator cuff tendon tears.

Our study aligns with prior research, which has highlighted the advantages of using 3D MERGE MRI over 2D MRI for imaging rotator cuff tendon tears. Lee et al.[10] and Gyftopoulos et al.[13] discovered that the application of 3D MRI significantly enhanced the accuracy of identifying the morphologies of rotator cuff tears, compared to 2D MRI. Additionally, Muto et al.[22] provided further evidence to support this claim, stating that 3D MRI demonstrated considerably higher accuracy in diagnosing rotator cuff tear morphology than 2D MRI. The findings from these studies reinforce our hypothesis that 3D MRI, particularly with multiplanar reconstruction techniques such as PDFS or MERGE 3D technique, may yield more precise and reliable information regarding the morphology of RCT tears compared to 2D MRI.

The primary difference lies in the sensitivity rates observed for crescent tears, which were 88.2% with 3D MERGE MRI and 70.6% with 2D MRI. Our findings show that 3D MRI exhibits greater specificity compared to 2D MRI in detecting longitudinal tears. This suggests that 3D MRI is more effictive at distinguishing longitudinal tears from other types of tears, which are often misidentified as large or degenerative tears when using 2D MRI. No significant difference was detected between 3D MERGE MRI and 2D MRI regarding massive tears due to the ease of identifying such tears. Overall, our findings show that 3D MERGE MRI with multiplanar reconstruction outperforms 2D MRI in categorizing the full spectrum of rotator cuff tear shapes.

Our study showed that 2D MRIs provide a lower sensitivity in detecting crescent tears, which are the most common type of RCT tears. This reduced sensitivity may be attributed to the fact that crescent tears are often found in the anterior or posterior aspects of the supraspinatus tendon, making them challenging to identify using 2D MRI scans in the sagittal or coronal planes. Habermeyer et al.,[23] emphasized the challenges associated with identifying crescent tears in the supraspinatus tendon using 2D MRI in these planes. They discovered a strong association between the categorizations of Ellman and Snyder but were unable to show the extent of partial-thickness rotator cuff tears in the transverse and coronal planes. The Thomazeau classification system provides a detailed framework for evaluating rotator cuff tears by considering tear dimensions in both the sagittal and coronal planes, which adds to the complexity of the assessment.[24] 3D MRI Studies have demonstrated that 3D MERGE MRI is superior to 2D MRI in accurately determining the morphology of RCT tears, especially crescent-shaped injuries.[13,16] 3D MRI may not show superiority over 2D MRI in diagnosing full-thickness supraspinatus tears.[15] However, 3D MRI provides more comprehensive data regarding the dimensions, extent, and retraction of RCT tears, which is essential for surgical strategizing and prognosis.[11,12,16] In addition, 3D MRI can generate images in the axial or oblique plane, providing a more comprehensive visualization of crescent tears. These tears are found in the anterior or posterior aspects of the supraspinatus tendon, and the 3D reconstruction allows for a clearer assessment of their size and shape.[12,13]

The morphology of RCT tear is an essential factor in preoperative assessment and surgical planning, as it impacts biomechanical characteristics, the feasibility of repair, and overall prognosis.[25] Arthroscopic repair is the preferred method for treating crescent tears; however, massive tears cary a higher risk of failure and are associated with poorer functional outcomes.[14] A thorough evaluation of RCT morphology tear is crucial in selecting the most suitable surgical approach and predicting the postoperative results.[26] Developing surgical approaches, such as patch repair and muscle tendon transfer, are being used to manage severe RCTs. It is also important to be aware of the postoperative MRI appearances to assess the outcomes of these procedures.[27] This knowledge can assist surgeon in formulating the most effective surgical approaches and predicting postoperative outcomes. Lambert et al.[28] and Okoroha et al.[29] have shown that 3D MRI offers enhanced precision and comprehensive insights into rotator cuff tears, resulting in enhanced surgical strategizing and better postoperative results. These studies advocate for the use of 3D MERGE MRI in orthopedic surgery due to its capacity to enhance precision and improve patient results.

Research has shown that 3D MRI provides more accurate assessments of the size and shape of rotator cuff tears compared to 2D MRIs, which can be beneficial in planning surgical procedures.[13,22] It is also crucial to note that the precision of these measurements may vary depending on the imaging modality used, with ultrasound typically yielding smaller readings than MRI.[29] Both 3-T MRI and 3-T MR Arthrography have demonstrated comparable diagnostic precision in identifying complete and partial rotator cuff injuries. However, 3-T MR Arthrography exhibits a slight advantage in reliably detecting tears in the subscapularis muscle.[15]

The results of our study showed that employing a 3D MERGE MRI was more precise, reliable, and comprehensive compared to using two sequences of coronal and sagittal planes for 2D MRI in determining the morphology of full-thickness RCT tears. We acquired the MERGE coronal sequence alongside standard 2D MRI and subsequently performed manual image reconstruction for 3D visualization utilizing segmentation and volume rendering techniques. The MERGE sequence was selected due to its demonstrated ability to offer superior contrast and segmentation of rotator cuff tendons and muscles in 3D MRI, in comparison to the PDFS sequence.[11,13] The advancement of a wide-field 3D ultrasound platform, coupled with a semi-automatic 3D segmentation algorithm, has improved imaging capabilities. This technology has been proven to accurately identify and delineate rotator cuff tear sites, closely aligning with the ground truth.[30] However, the choice of imaging techniques may be influenced by individual tear features, as various kinematic patterns have been seen in extensive rotator cuff tears.[31-34] Additionally, The Fast spin echo (FSE) approach has been identified as a viable alternative to conventional spin-echo imaging for detecting rotator cuff tears, albeit with certain limitations.[31,32] Our findings indicate that using a 3D MRI method with a single MERGE sequence can effectively replace the traditional 2D MRI method that needs two different sequences for coronal and sagittal planes. This transition can enhance the visualization of RCT tear morphology and improve the management and surgical planning for RCT tear patients.

Utilizing 3D MERGE MRI to evaluate rotator cuff tendon injuries presents several advantages over 2D MRI. This technique allows for the visualization of the tendon in any desired plane without compromising resolution or signal-to-noise ratio, resulting in a more precise and thorough evaluation.[22] On the other hand, 2D MRI is restricted by predetermined imaging planes and may be affected by partial volume averaging artifacts, which may obscure or distort the shape of the tear.[22] The diagnostic utility of arthrography and plain radiography in identifying rotator cuff tears is restricted; however, arthrography demonstrates moderate accuracy in detecting full-thickness tears.[33] Notably, the common imaging characteristics of subacromial impingement can be observed in both symptomatic and asymptomatic patients, complicating the definitive diagnosis of the condition. [34] Although there are concerns regarding image blurring and unclear structural margins, 3D isotropic MR arthrography has been suggested as an alternative imaging technique for identifying rotator cuff tears and labral lesions.[10]

The accurate identification of the shape and size of the tears in the RCT, as well as other injuries such as avulsion injuries, is essential for effective treatment planning and prognosis among professional athletes.[13,35,36] Studies have demonstrated that utilizing 3D MRI with multiplanar reconstruction significantly enhances the precision of identifying tear shapes compared to 2D MRI.[13,16] This technique has the capability to identify minuscule tears and enhance surgical preparation by offering more precise measurements of tear dimensions and tendon condition.[28] Therefore, the utilization of 3D MERGE MRI is highly advantageous for physicians in planning the most effective treatment plans and predicting the prognosis of rotator cuff restoration.

The enhanced sensitivity of 3D MERGE MRI in detecting crescent-shaped tears can be attributed to its ability to overcome the limitations of anatomical orientation found in conventional 2D MRI. Crescent tears typically occur in the anterior or posterior supraspinatus tendon and may not be fully visualized on standard coronal and sagittal images.[23] The multiplanar capability of 3D MERGE MRI allows for the analysis of the RCT in various planes, leading to a more definitive characterization of tear morphology that is not possible with 2D MRI.[12,13]

This study demonstrates the enhanced sensitivity, specificity, and accuracy of 3D MERGE MRI in characterizing rotator cuff tears compared to conventional 2D MRI. This finding aligns with other studies that have shown enhanced diagnostic accuracy with 3D MRI for rotator cuff tears. In our evaluation, we utilized a 3D MERGE MRI protocol that has demonstrated superior contrast and detail in assessing rotator cuff pathology compared to other 3D options, such as 3D PDFS sequences.[12,17,18] However, there is a lack of comparative studies between alternative 3D MRI sequences for the categorization of rotator cuff tears, which warrants further investigation.

The improved diagnostic performance of 3D MERGE MRI has significant clinical implications for surgical decision-making. Unlike 2D MRI, the isotropic nature of 3D imaging enables detailed visualization of tear dimensions, particularly for crescent and longitudinal morphologies. For instance, the superior delineation of tear size and orientation provided by 3D MRI aids in determining whether to use single-row or double-row repair techniques, potentially improving repair success rates.[13] Accurate preoperative assessment of tear size and shape allows for guidance in repair strategies, including the approach to mobilization, the choice between single or double-row fixation, and the prediction of repair success.[14,26] The advanced tear characterization provided by 3D MRI has the potential to optimize patient outcomes; however, further research is necessary to determine its impact on postoperative function. imaging diagnostics and postoperative outcomes to confirm

### *Strengths*

This study is innovative and robust due to several key strengths. Firstly, arthroscopy, which is a more accurate gold standard than MRI, was used to diagnose rotator cuff injuries. This approach allowed for precise measurement of the sensitivity and specificity of 3D MERGE MRI compared to 2D MRI. Secondly, we included objective outcome measures, such as tear size in millimeters as determined by both MRI and arthroscopy, to compare the dimensional accuracy of imaging modalities. Thirdly, standardized radiology reporting systems were used to interpret shoulder MRI, facilitating an assessment of the agreement between the imaging modalities and arthroscopy. Lastly, we compared the diagnostic accuracy of 2D and 3D MRI for various types of rotator cuff tears: crescent, longitudinal, and massive.

### *Limitations*

This single-center, retrospective study may limit the broader applicability of its results. The study focuses on the 3D MERGE MRI technique but does not compare it to other advanced 3D methods, such as 3D PDFS or 3D SPACE. While MERGE MRI demonstrates superior diagnostic accuracy, comparative analyses with other 3D techniques could further validate these findings. Manual segmentation performed by a single technologist may introduce variability, suggesting that semi-automated methods could improve standardization. Although radiologists were blinded to arthroscopy results, they were not blinded to clinical presentations, which may introduce bias. Furthermore, longitudinal U-shaped and L-shaped tears were classified together, potentially overlooking functional differences. Future research should investigate the correlation between enhanced tear characterization and improved clinical outcomes, utilizing multicenter trials and comparisons of alternative 3D imaging techniques to validate findings. Variability in MRI interpretations due to differences in radiologist experience may affect the generalizability of our findings, despite our adherence to standardized protocols. Additionally, manual segmentation of images may introduce subjectivity, and the use of a single 3T MRI system limits the applicability of results to other systems or imaging protocols.

While this study focuses on the short-term diagnostic accuracy of 3D MRI, the potential long-term impact of this technique on surgical outcomes and patient recovery warrants discussion. The enhanced precision in characterizing rotator cuff tear morphology provided by 3D MRI may allow for more accurate surgical planning, including the choice between single-row and double-row repair techniques, as well as the necessity for augmentation strategies. This could lead to reduced re-tear rates, improved functional outcomes, and shorter recovery times. Studies have shown that accurate preoperative assessment is critical for selecting appropriate interventions and predicting long-term success, particularly for complex tear morphologies such as crescent and longitudinal tears. Future studies should investigate the correlation between improved

these hypotheses.

## Conclusion

3D MERGE MRI improves the diagnosis of RCT tears compared to standard 2D MRI, especially for crescent-shaped tears, thereby facilitating preoperative assessment and surgical decision-making. Its multi-view capability aids in selecting appropriate surgical interventions and predicting outcomes, which could significantlyimprove patient care. However, further studies are necessary to confirm its benefits across various clinical settings and MRI machines. This advanced MRI technique holds the promise of better diagnosis and treatment, with the goal of improving patient outcomes and minimizing the impact of injuries.

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***Declaration of Ethical Approval for Study:*** In the review of the cases, confidentiality and other ethical principles were upheld, and the examination of the cases was conducted with written permission from the university's ethics committee. All stages of this study were conducted in accordance with the Helsinki ethical principles and have been approved by the Ethics Committee of Tehran University of Medical Sciences. This research was presented on 27/05/2020 to the organizational ethics committee of the Tehran University of Medical Sciences under the title "Comparing 3D MERGE MRI and 2D MRI for Rotator Cuff Tear Evaluation and Surgical Planning" and was approved with the code IR.TUMS.IKHC.REC.1399.116.

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